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B70 01016

SUBJECT: Preliminary Evaluation of Water
Loss Effects During EVA - Case
320

DATE: January 12, 1970

FROM: T. A. Bottomley

ABSTRACT

This memorandum examines the time constraints imposed on an astronaut when he lacks the functional capability for ingesting water or eliminating urine during EVA. The modes and rates of body water losses are discussed and the safe physiological limits for dehydration and urine accumulation are defined. These limits are:

- a) 2% weight loss due to dehydration resulting in severe thirst, elevated heart rates, and reduced work capacity, and
- b) discomfort resulting from the need to micturate (urinate).

The results of the study indicate that Apollo EVA duration should be limited to a maximum of six hours to avoid functional impairment due to dehydration and to minimize discomfort caused by strong thirst and the need to micturate. If 1-2% body weight loss to water experienced in earlier Apollo flights is anticipated prior to EVA, the duration of EVA should not exceed the four-hour period demonstrated to be attainable on Apollo 12. Extension of EVA time beyond these limits does not appear feasible unless arrangements are provided for water ingestion and urine collection in the EMU during lunar surface excursions.

(NASA-CR-112561) PRELIMINARY EVALUATION OF
WATER LOSS EFFECTS DURING EVA (Bellcomm,
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MEMORANDUM FOR FILE

INTRODUCTION

Included in the constraints which may be time-limiting during lunar surface extravehicular activity are physiological concerns with regard to dehydration and urine elimination (micturation). While the EMU is designed to accommodate provisions for water ingestion and elimination during pressurized suit operations, maintenance of pressure integrity and comfort have mitigated against using the devices provided for intravehicular use to supply water and collect urine during EVA.

This memorandum examines the effects of denying these functions to the extravehicular astronaut. The findings are considered preliminary because subject variability and non-linearities in some water loss modes have not been considered fully in the quantitative data.

DISCUSSION

About 90% of the crewmembers' water requirement is supplied by direct ingestion. The remaining 10% is obtained as a by-product of food oxidation. The amount of water ingested directly is influenced by diet, opportunity, environment and individual preference. Water is retained as needed to establish a suitable water/electrolyte balance in the body. Reliance on the thirst mechanism for regulating water intake, especially where supplies are limited, usually results in voluntary dehydration.¹

Excessive water losses were common during early space flights when sweat losses were heavy. It became necessary, therefore, for Medical Operations to program the flight crews' water intake. Programmed ingestion under control of the astronaut is still followed on Apollo flights. Despite this measure, crew weight losses during the Apollo VII and VIII flights ranged from 2.8 to 6.4 percent. The average weight loss was 4.5% for the six crew members. The amount of actual body water lost is uncertain. Fluid intake by the Apollo VII and VIII crews during the first 24-hours after recovery restored, on the average, only one-third of the total weight loss.² This suggests that the extent of dehydration was within the range of 1-2% of total body weight.

Programmed ingestion of water in small amounts, at frequent intervals, is recommended over infrequent ingestion of large amounts (e.g. 1 to 2 liters). While the intake of a large amount of water at one time will reduce physiological strain during stress from heat or high work loads, it may cause excessive water loss (diuresis). Diuresis will result in a net loss of body water by the end of the EVA. Ingestion of large amounts of water at one time also may provoke gastric distress and nausea.¹

The avenues of water loss are:

- a. defecation
- b. micturation
- c. sensible (i.e. visible) perspiration, and
- d. insensible water from the lungs and skin.

The estimated total water loss in pounds and as a percentage of total body weight during lunar EVA is shown in Figure 1 as a function of EVA duration. Water loss to defecation is not shown. This loss is approximately equal to metabolic production (about 10%) and is less than the probable error in the overall summation.

Micturation loss normally averages about 1500 ccs/day. Nominal values range from 1200 to 1800 ccs/day. Wider variations are possible ranging from 400 cc/day (the minimum required for adequate elimination of waste)³ to more than 4000 ccs/day (after ingesting large quantities of liquids).¹ Urine output normally is reduced as dehydration is increased. Production is approximately halved if body dehydration is about 2%. It approaches asymptotically the minimum amount needed to eliminate waste from the kidneys (i.e. 400 cc/day) when body dehydration approximates 5-6 percent.⁴ This non-linearity is not reflected in Figure 1.

The urge to micturate occurs when about 300 cc's have accumulated in the bladder.⁵ As shown in Figure 1, the micturation urge will occur about 4.8 hours into the EVA at the nominal accumulation rate of 1500 cc's/day. The urge may occur as early as 4 hours or as late as 6 hours for the nominal range of accumulation rate values. The urine accumulation which will cause painful discomfort is not known by the writer. If it is postulated that an accumulation of 450 cc's results in extreme discomfort and that this condition is acceptable only in case of contingency, then the emergency time-in-suit limit for withholding micturation ranges from 6 to 9 hours.

Sweat losses are shown on Figure 1 at the design maximum rate (130 gms/hr) permissible in accordance with the EMU specifications.⁶ Based on experimental data, these rates may be realized by a man working at 1000 Btu/hr near the high temperature boundary of the comfort zone. While this sweat rate is representative of a worst case condition, the demonstrated fact that the crewmember is a poor judge of thermal comfort and, therefore, provides very coarse control of the Apollo EMU thermal control system, establishes that this worst case condition is real. Variations in metabolic rate from 500 to 2000 Btu/hr can result in variations in sweat rate from 20 to 300 gms/hr along the high temperature boundary of the comfort zone. The design of the EMU does provide for regulating the thermal control subsystem to maintain sweat rate at or below the specification limit over most of the 500-2000 Btu/hr range. Accordingly, operational procedures can be implemented to reduce body dehydration due to water loss from sweating. For the purposes of this study, a sweat rate of 130 gms/hr appears to be a reasonable assumption as an upper limit for a crewmember whose average workload approximates 1000-1200 Btu/hr over the EVA period.

Insensible water loss is commonly defined as non-visible moisture loss from the lungs and skin by the processes of vaporization and diffusion. Insensible moisture loss varies inversely with ambient total pressure and vapor pressure. At the hypobaric suit pressure of 3.75 psia, insensible water loss from the lungs and skin will exceed normal losses (at one atmosphere) by a factor of 4 or more for the same temperature and workload conditions. Under constant environmental conditions, insensible water loss from the skin is essentially invariant. However, lung water loss varies directly with workload since respiration rate increases linearly with metabolic rate.

It is assumed also in Figure 1 that the astronauts have emptied their bladders and are not dehydrated at the beginning of EVA. If these assumptions are valid, the crew should be able to work extravehicularly in a pressurized suit for a maximum of six hours before thirst* and the need to micturate make it necessary to terminate the EVA. If, however, they experience the 1-2% dehydration common to crews on earlier flights, their desire for water and considerations of fatigue and safety argue for terminating each EVA at four hours as demonstrated on Apollo 12.

*Both Apollo 11 and 12 crewmembers mentioned being very thirsty at the end of their 3-4 hour EVAs.

Some effects of dehydration up to 5% (not indicated on Figure 1) are as follows:¹

- 1-3% Higher heart rate in submaximal work and decreased time to exhaustion at maximal work.
- 4-5% Deterioration of isometric muscle strength; economy of movement, weariness, apathy, nausea and emotional instability.

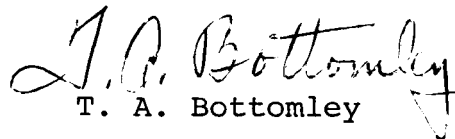
SUMMARY AND CONCLUSIONS

Assuming no urine accumulation at the start of EVA, the results of the study indicate that extravehicular crewmembers, working at 1000-1200 Btu/hr and operating near the high temperature boundary of their comfort zone, will reach the physiological limit(s) for:

- a) dehydration and micturation in a maximum period of six hours if they are not dehydrated when EVA is initiated, and
- b) dehydration in three or less hours if they have experienced the 1-2% inflight dehydration commonly noted on past Apollo flights.

Based on the results of this analysis, Apollo EVA duration should be limited to a maximum of six hours to avoid deleterious effects of excessive dehydration (>2%) and to minimize astronaut discomfort caused by strong thirst and the need to micturate. If 1-2% body weight loss to water is anticipated during the flight to the moon, maximum EVA duration should be limited to four hours to insure acceptable crew performance and safety. Extension of EVA time-in-suit limits beyond six hours does not appear feasible unless arrangements are provided for water ingestion* and urine collection in the EMU during lunar surface excursions.

The current program for frequent ingestion of small amounts of water by Apollo crews should be continued with special emphasis given during training and flight operations of the need to avoid inflight dehydration and the risk of diuresis.


T. A. Bottomley

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Attachment
Figure 1

¹A drinking water supply containing about one pint is under development by MSC/CSD for EVA use. Earliest effectivity will be Apollo 13.⁷

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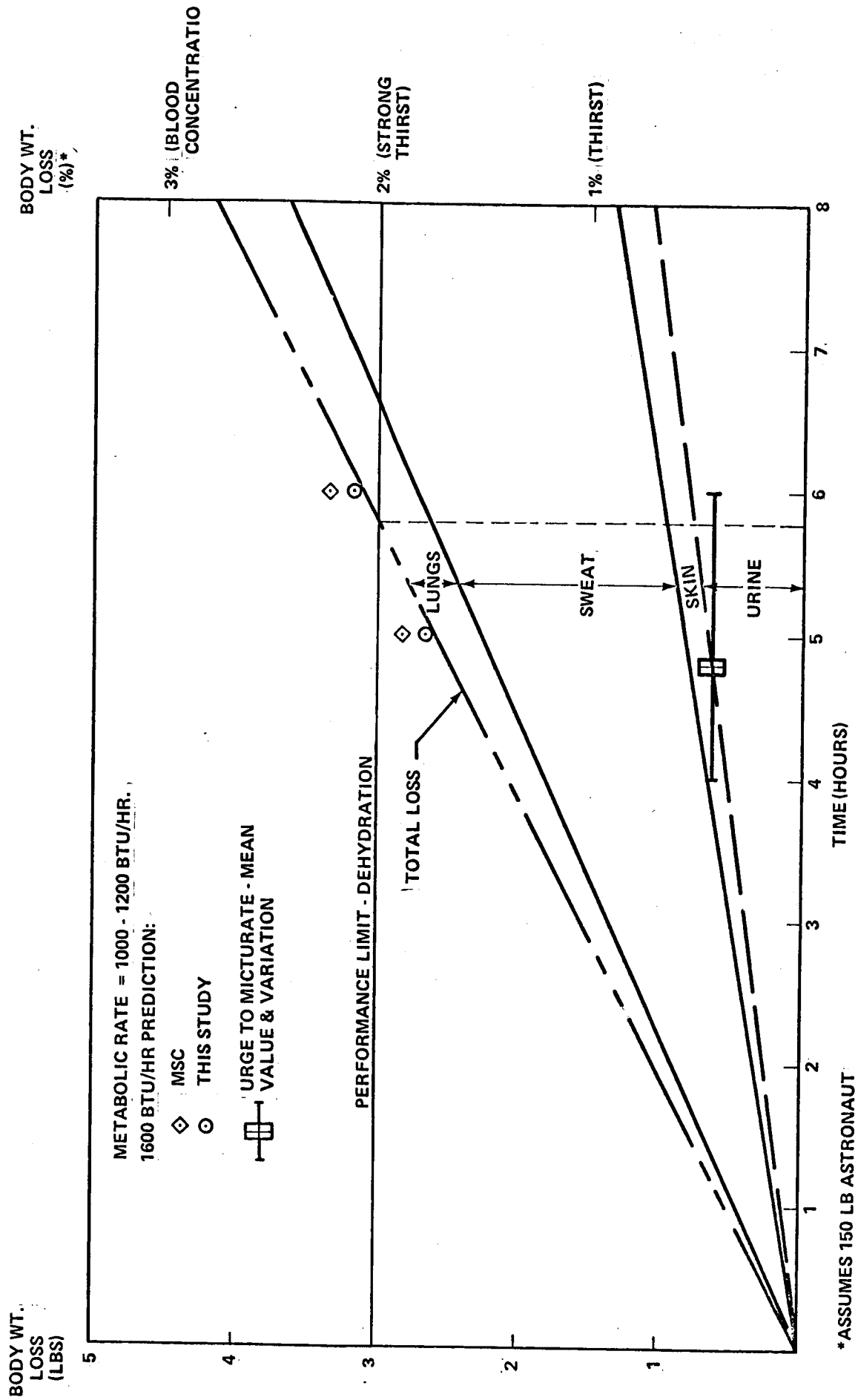


FIGURE 1 - PREDICTED WATER LOSS DURING LUNAR SURFACE EVA

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